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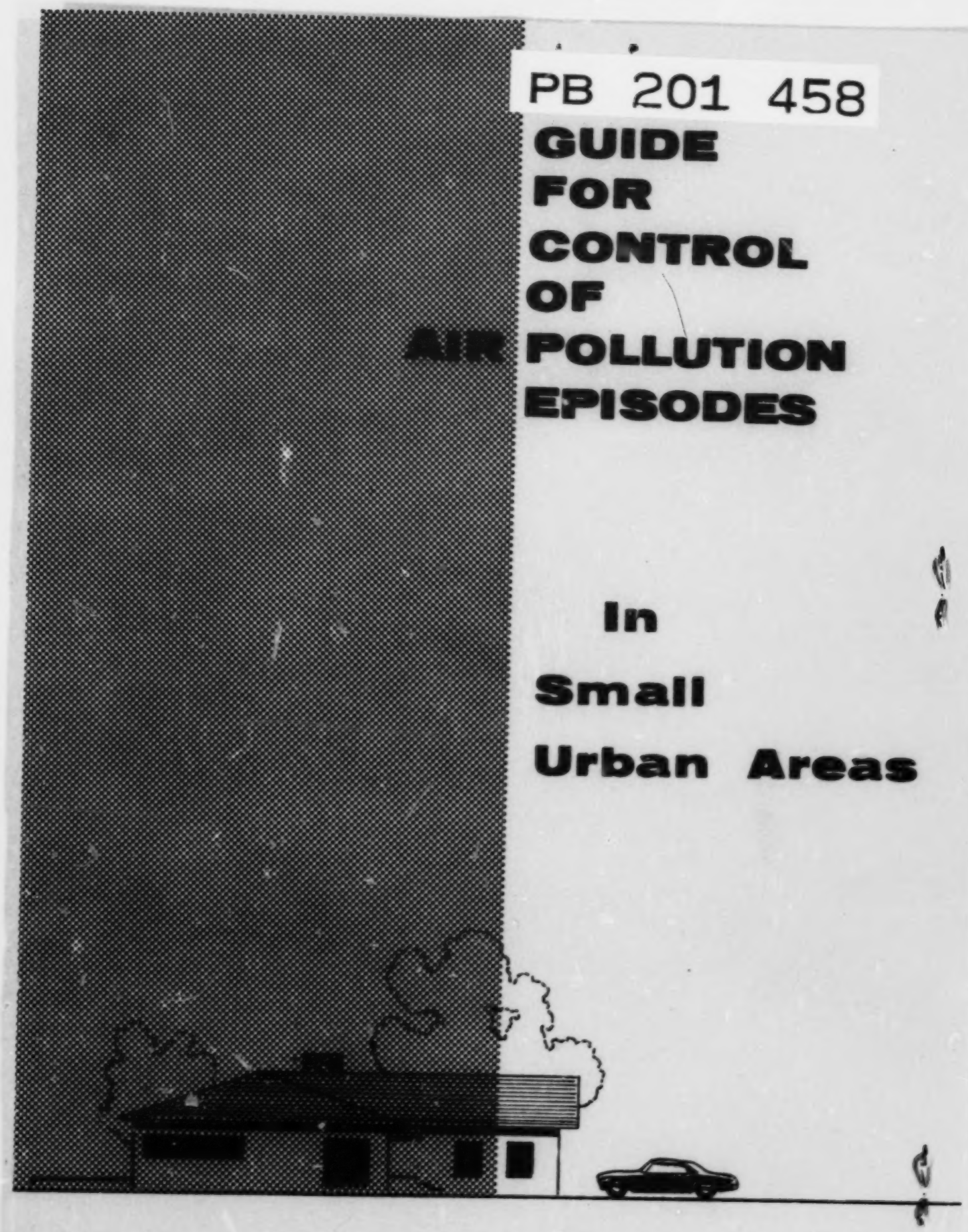
AIR GUIDE FOR CONTROL OF POLLUTION EPISODES

In Small Urban Areas



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67

GUIDE FOR CONTROL OF AIR POLLUTION EPISODES IN SMALL URBAN AREAS

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A manual to assist local air pollution officials with the design and implementation of Emergency Action Plans for the avoidance of air pollution episodes is presented. The manual is directed toward the needs of relatively small cities. Section 2 presents the following information as as aid in understanding and defining the factors that constitute an air pollution episode: the nature and effects of atmospheric pollutants; and meteorological factors related to air pollution episodes. Section 3 discusses the formulation and operation of a typical Emergency Action Plan. Section 4 presents a list of items to be considered when formulating an Emergency Action Plan.

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GUIDE FOR CONTROL OF AIR POLLUTION EPISODES IN SMALL URBAN AREAS

1. INTRODUCTION

1.1 OBJECTIVE

This manual has been made available through the efforts of the Air Pollution Control Office's (APCO's) Emergency Operations Control Center and is intended to assist local air pollution control officials concerned with the design and implementation of emergency action plans for the avoidance of air pollution episodes. In this document, an air pollution episode is defined briefly as the occurrence of stagnant air masses during which air pollutants accumulate, so that the population is exposed to an elevated concentration of airborne contaminants. It is not specifically designed for utilization in the "man-made" type incident in which an accident or spill results in a localized fumigation of emergency proportions. Much of the direction provided herein, however, will be applicable to such a situation.

1.2 SCOPE

The manual is directed toward the needs of relatively small cities. A city with a nominal population of 10,000 to 30,000 cannot be expected to have a highly sophisticated air pollution control authority and often must rely on the State agency for overall guidance. Limited but effective control actions can be taken in any area, however; it is not essential that sophisticated air quality monitoring capabilities and other specialized technical expertise be immediately available. In spite of limited technological capabilities, local agencies may be able to take effective action owing to their great familiarity with their jurisdiction. This manual is then restricted to some of the more basic procedures and should be a valuable reference for those local air pollution control authorities with limited resources at their disposal.

1.3 EPISODE BACKGROUND

The occurrences of air pollution episodes are becoming more frequent with the growth of our society. Reported critical periods of air pollution date back as far as 1873. London has had ten reported episodes since that date; New York City has had seven reported episodes since 1953. At least two of the latter were general episodes for the entire Eastern United States. Other well-known episodes occurred in the Meuse Valley of Belgium and in Donora, Pennsylvania. Minor "incidents" have been reported for St. Louis, Missouri; Cincinnati, Ohio; Wierton, West Virginia; Rotterdam, Holland; Hamburg, Germany; and Osaka, Japan. Critical periods of smog have occurred frequently in Los Angeles, California; and outbreaks of asthma have been reported for New Orleans, Louisiana, and for the Tokyo-Yokohama area of Japan.

Many incidents of air pollution episodes are borderline cases, and they may go unreported. An episode may occur for a short period of time but not be reported in the technical literature because the number of people severely affected is not large enough to attract public attention. The 1953 episode in New York was not reported until 9 years later.

Some general indicators of air pollution episodes that can be derived from the reported literature are:

1. Prolonged anticyclonic weather systems were present.
2. Temperature inversions were noted.
3. Wind speeds were low.
4. Concentrations of smoke, sulfur dioxide, and other pollutants increased to critical levels.
5. Mortality associated with peak concentrations of air pollutants increased.
6. Morbidity was also related to the air pollution levels encountered.
7. The effects were prompt.
8. Death and illness occurred in all age groups.
9. Excessive death rate occurred with increasing age.
10. Effects of episodes on health seemed to be due to a combination of several pollutants.
11. Deaths generally resulted from the breakdown of human respiratory or cardiovascular systems.
12. Cough and eye irritation were shown to be related to episode pollution levels.
13. The duration of episodes generally ranged from 2 to 7 days.

14. Species other than man may have succumbed to the air pollution dosages received.

Detailed documentation is not available on most reported air pollution episodes, especially those occurring before 1957. Lynn, Steigerwald, and Ludwig have described in some detail the November-December 1962 air pollution episode in the Eastern United States.[1] During this episode, benzene-soluble organics rose to 7 times their normal, and total particles rose to approximately 4 times their normal. Carbon monoxide, nitrogen oxides, and sulfur dioxide were also elevated 3 to 6 times their normal.

Fensterstock and Fankhauser have reported on the Thanksgiving 1966 air pollution episode in the Eastern United States.[2] Peak pollution levels were recorded during this episode, and the death rate increased by approximately 24 deaths per day.

Awareness of air pollution is growing, and techniques for monitoring levels of pollution are improving. Episode frequency is increasing, as demonstrated by Figure 1-1, which shows the frequency of air pollution episodes as reported in the literature.

High Air Pollution Potential Advisories (HAPPA), issued daily by the National Weather Service, were initiated on a regular basis in August 1960. Advance warnings of meteorological conditions conducive to the accumulation

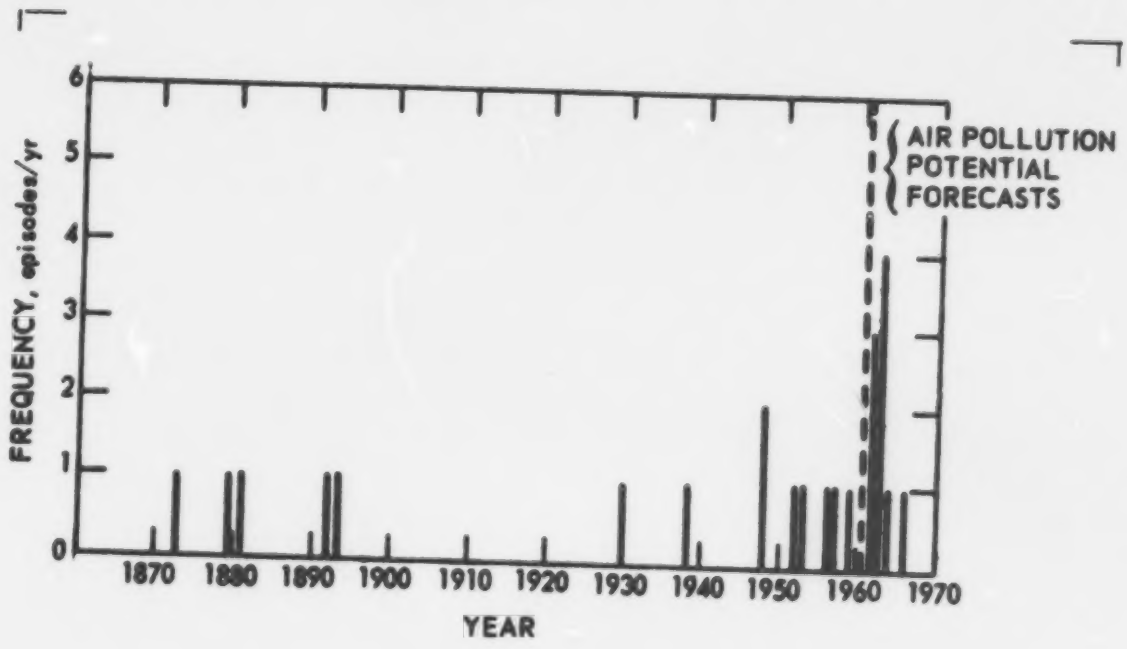

Figure 1-1. Frequency of air pollution episodes.

of air pollution are provided by this system. To provide the service, a set of semi-arbitrary technical conditions has been selected for defining high air pollution potential. These advisories, plus their possible utilization, will be discussed later in this guide.

In general terms, a description of weather conditions conducive to air pollution episodes is as follows:

1. A high-pressure system becomes almost stationary over the area for several days.
2. No precipitation occurs.
3. Temperatures are generally above normal.
4. Winds range between 0 and 7 miles per hour near the surface, and are relatively light aloft to at least 18,000 feet (500 millibars).
5. Air at higher elevations is slowly sinking and warming (subsidence).
6. Air in the low levels is stable, that is, it exhibits little motion or mixing in the vertical layers.
7. Temperature in these layers increases with height (inversion) instead of decreasing as is normal.

From a meteorological standpoint, a weather situation conducive to the accumulation of high concentrations of air pollutants is said to have "high pollution potential," whether pollutant sources actually exist in the underlying air or not.

2. DEFINITIONS OF EPISODE FACTORS

High concentratons of man-made pollutants in the air have produced the following observed effects:

1. Reduction of visibility.
2. Deterioration of fabrics, metals, and building materials.
3. Damage to vegetation and animals.
4. Injury to man.

If, under chronic conditions, the pollutant levels are sufficient to produce some of these manifestations, then, under acute (episode) conditions, these effects can interact to create an emergency or, perhaps, a disaster. When the population is subjected to these extreme pollution levels, public concern and cooperation are at a maximum. Compulsory and voluntary emission reduction is most easily justified and obtained, provided proper direction is available from the local authority. Thus, this section deals with information that should help the local authority to understand and define the factors that constitute an air pollution episode. A glossary of air pollution terminology can be found in Appendix A.

2.1 ATMOSPHERIC POLLUTANTS– THEIR NATURE AND EFFECTS

2.1.1 Particulates

Particles of solid–and occasionally liquid–matter in the air constitute a relatively small but important portion of polluted community air in most cities and towns in the United States. These so-called particulates may be either so large that they rapidly settle to the ground, or so small that they remain suspended in the air until they are removed by such natural phenomena as rain or until they are inhaled by people. Particulates may be quite complex in their chemical composition. The organic materials found in airborne particles may

contain aliphatic and aromatic hydrocarbons, acids, bases, phenols, and other compounds. Airborne particles may also contain any of a wide range of metallic elements; those most commonly found are silicon, calcium, aluminum, iron, magnesium, lead, copper, zinc, sodium, and manganese. Sources of particulates include such activities as fuel combustion, various manufacturing and processing operations (production of steel, cement, and petroleum products), and open burning and incineration of refuse.

Particulate air pollution is widely regarded as objectionable because it is often aesthetically bothersome. It interferes with visibility and is associated with soiling and corrosion of metals, fabrics, and other materials. Its adverse effects on health are far more subtle but, nonetheless, significant. In general, concern about the health effects of particulates is related to (1) the ability of the human respiratory system to remove particulates from inhaled air and retain them in the lung, (2) the presence in some particulates of mineral substances having toxic or other physiological effects, (3) the presence in particulates of polycyclic hydrocarbons having demonstrated carcinogenic (cancer-producing) properties, (4) the demonstrated ability of some fine particles to increase the harmful physiological activity of irritant gases when both are simultaneously present in inhaled air, and (5) the ability of some mineral particulates to increase the rate at which sulfur dioxide in the atmosphere is converted by oxidation to the far more physiologically active sulfur trioxide.

The size of airborne particles has an important bearing on whether and to what extent they will reach the lungs. Most coarse particles–those about 5 microns or more in diameter–lodge in the nasal passages. Smaller particles are more likely to penetrate into the lungs; the rate of penetration increases with decreasing particle size. Particles smaller than 2 to 3 microns usually reach the deeper structures of the lungs where there is no protective mucous blanket.

The ability of particles to accentuate the adverse physiological effects of simultaneously inhaled gas is one of the most important aspects of the health hazard of particulate air pollution. Combinations of gases and particles have been shown to cause toxicity changes in rodents, resistance to airflow in the respiratory tract, and bactericidal action.

Air quality criteria for particulate matter can be found in Appendix B.

2.1.2 Sulfur Oxides

The sulfur oxides (SO_X) that are of concern as atmospheric pollutants are sulfur dioxide, sulfur trioxide, and their acids and acid salts. Fossil fuels such as coal and petroleum contain elemental sulfur; when the fuel burns, the sulfur is converted to sulfur dioxide and, to a lesser degree, sulfur trioxide. Because fossil fuels are burned extensively in the United States to heat buildings and to generate electric power, pollution of the atmosphere with SO_X is widespread

and is especially prevalent in cities. Petroleum refineries, smelting plants, coke-processing plants, sulfuric acid manufacturing plants, coal-refuse banks, and refuse-burning activities are also major sources of sulfurous pollution.

The evidence is considerable that SO_x pollution aggravates existing respiratory diseases in humans and contributes to their development. Sulfur dioxide alone irritates the upper respiratory tract; adsorbed on particulate matter, the gas can be carried deep into the respiratory tract to injure lung tissue. Sulfuric acid, when inhaled in a certain particle size, can also deeply penetrate the lungs and damage tissue.

The documented severe air pollution episodes had common factors: they occurred in heavily industrialized areas during relatively brief periods of anticyclonic weather conditions; sulfur dioxide levels were excessively high, as were levels of other gaseous and particulate pollution. Although the pattern of effects was not perfectly uniform in all these episodes, generally the elderly, the very young, and those with pre-existing cardiorespiratory disease were most affected.

Epidemiological and clinical studies substantiate the evidence that certain portions of the population are more sensitive than others to SO_x pollution. For example, prolonged exposures to relatively low levels of sulfur dioxide have been associated with increased cardiovascular morbidity in older persons; prolonged exposures to higher concentrations of sulfur dioxide have been associated with an increase in respiratory disease death rates and an increase in complaints of nonproductive cough, mucous membrane irritation, and mucous secretion by school children; the residual air in the lungs of emphysematous patients has been reduced significantly when the patients breathed ambient air that had been filtered of pollutants.

Sulfur oxides pollution can also adversely affect the more robust segments of the population. Experiments in which healthy human volunteers were exposed to sulfur dioxide concentrations several times higher than the taste threshold concentration indicate that such exposures will produce pulmonary function changes including increased respiration rates, decreased respiratory flow rates, and increased airway resistance. The impairment of function was greater when the sulfur dioxide was administered together with particulate matter.

Air quality criteria for SO_x can be found in Appendix B.

2.1.3 Carbon Monoxide

Carbon monoxide (CO) is one of the most common of all urban air pollutants and one of the most harmful to man. Its ability to impede the oxygen-carrying capacity of the blood makes it lethal in high concentrations. Though all processes involving combustion of carbonaceous material produce

CO, the motor vehicle is by far the most important source from which this pollutant gas reaches the atmosphere. The wide use of motor vehicles, coupled with the fact that they discharge pollutants from points close to the gound, makes them the prime contributor to most people's daily exposure to CO. Federal standards to control carbon monoxide emissions from new motor vehicles have been established and became effective beginning with 1968 model cars and light trucks.

Carbon monoxide poisoning is a well-understood phenomenon. As with many other harmful gases, the degree of damage that man sustains as a result of exposure to CO is related to the concentration of the gas in inhaled air and the length of exposure. The hazards of CO arise mainly from its strong affinity for hemoglobin, which carries oxygen to body tissues. The effect of CO combining with hemoglobin is to deprive the tissues of needed oxygen. At concentrations of slightly more than 1,000 parts per million (ppm), CO kills quickly. Fifty parts per million is now recommended as the upper limit of safety for healthy industrial workers exposed for an 8-hour period. At approximately 100 ppm, most people experience dizziness, headache, lassitude, and other symptoms.

In the January 1956 smog episode, CO concentrations in the ambient air reached 50 ppm in London and 80 ppm in Salford, England. Inside automobiles, concentrations were undoubtedly considerably higher. For comparison, the average CO level in London during 1955 was 15 ppm.

It is quite possible that during episodes, the levels of CO that are reached both in vehicles and close to the highways are frequently high enough to affect some especially susceptible persons, such as those already suffering from a disease associated with a decrease of oxygen-carrying capacity of the blood (e.g., anemia) or those suffering from cardiorespiratory disease. The extra burden that is placed on the body by the reduction of the oxygen-carrying capacity of the blood induced by CO may cause injury to vital organs. People already burdened by the presence in their blood of unusual amounts of CO because of tobacco smoking or occupational exposure may also be adversely affected by the extra amount of CO they inhale from contaminated air.

Air quality criteria for CO can be found in Appendix B.

2.1.4 Oxidants

Oxidants are a major class of compounds found in photochemical smog—a major air pollution problem caused by atmospheric reactions of gases derived from the combustion of organic fuels. Emissions from motor vehicles are a prime factor in the formation of photochemical smog in virtually all parts of the country. Other factors that contribute to smog formation are the combustion of fuels for heat and electric power, burning of refuse, evaporation of petroleum products, and handling and use of organic solvents. The principal

identifiable oxidants in polluted urban air are ozone, the peroxyacyl nitrates (PAN), and the oxides of nitrogen (NO_X), primarily nitrogen dioxide (NO_2).

The most commonly experienced effect of photochemical smog is eye irritation. The components causing eye irritation have not been completely identified, but there is some correlation between the occurrence of eye irritation and overall levels of oxidant in the atmosphere. There is a characteristic pungent odor associated with photochemical smog. Ozone is an acrid component of this odor.

Studies have shown that it is harder for humans, particularly patients suffering from chronic respiratory disease, to breathe in areas having even a moderate level of photochemical air pollution (0.10 ppm total oxidant or higher). In clinical studies of patients with chronic bronchopulmonary disease exposed to the ambient Los Angeles smog for 1-week (when compared to the effects on the same patients breathing filtered air for a similar period), the most significant and uniform effect of photochemical smog exposure was an increase in oxygen consumption and a decrease in oxygen content of the blood (decrease in oxygen tension in arterial blood) during light exercise. Thus, while the patients were consuming more oxygen, less of it was being made available to the body. There also was greater difficulty in breathing by the patients (increased pulmonary airway resistance) when breathing the smoggy air.

Air quality criteria for oxidants and ozone can be found in Appendix B.

2.1.5 Oxides of Nitrogen

Oxides of nitrogen (NO_X) are an important group of atmospheric contaminants in many communities. They are produced during the high-temperature combustion of coal, oil, gas, and gasoline in power plants and internal combustion engines. The combustion fixes atmospheric nitrogen to produce the oxides. At the high temperatures, nitric oxide (NO) forms first; in the atmosphere it reacts with oxygen and is converted to NO_2. While this oxidation is very rapid at high concentrations, the rate is much slower at low concentrations. In sunlight, especially in the presence of organic material as typified by Los Angeles type photochemical smog, the conversion of NO to NO_2 is greatly accelerated.

Nitrogen dioxide, an acutely irritating substance, is considerably more toxic than NO. In equal concentrations, it is more injurious than CO. The proven effects of NO_2 on man and lower animals are confined almost entirely to the respiratory tract. With increasing dosage, acute effects are expressed as odor perception, nasal irritation, discomfort in breathing, acute respiratory distress, pulmonary edema, and death. The relatively low solubility of NO_2, however, permits penetration into the lower respiratory tract. Delayed or chronic pulmonary changes may occur from high but sublethal concentrations and from repeated or continuous exposures to lesser concentrations.

It should be noted, however, that other considerations such as plant damage, visibility reduction, or combined effects with other air pollutants may be more critical than the adverse health effects of NO_2 alone.

2.1.6 Other Pollutants

There are, of course, many air pollutants other than those mentioned here; and these may be of prime importance in specific localities. Since episode criteria have not yet been developed for these pollutants, they are not included here.

2.2 METEOROLOGICAL FACTORS RELATED TO AIR POLLUTION EPISODES

The most important part of training in air pollution meteorology is that portion concerned with recognizing meteorological conditions associated with air pollution episodes. Conditions that characterize large-scale air pollution potential are listed as the HAPPA criteria in Appendix C. For local authorities who receive no teletype weather service, there is a need to recognize the existence or imminence of local episode conditions that may or may not be part of a larger situation. Except for a difference in size of the affected area, criteria for episodes in a local community are the same as for a statewide area treated in a HAPPA.

2.2.1 Local Considerations

There is considerable variation in the types and degree of air pollution potential across the United States. The main factors causing these differences are emission characteristics, meteorology, and topography. For planning purposes, it is desirable to appreciate the nature of these differences, and it is necessary to identify the local "character" of a given area.

Diurnal variations are a part of the local "character" and influence the strategy of episode control. Seasonal variations, such as predominantly oxidant pollution in summer and sulfur dioxide pollution in winter, may exist in some areas.

The meteorological character of a region is determined by geographical location and local topography. Location identifies the broad-scale weather patterns that dominate the area, and topography accounts largely for local variations during particular weather situations. The National Oceanographic and Atmospheric Administration (NOAA) has adopted a classification based on similarity of weather conditions wherein the contiguous United States is divided into eight atmospheric areas, shown in Figure 2-1.

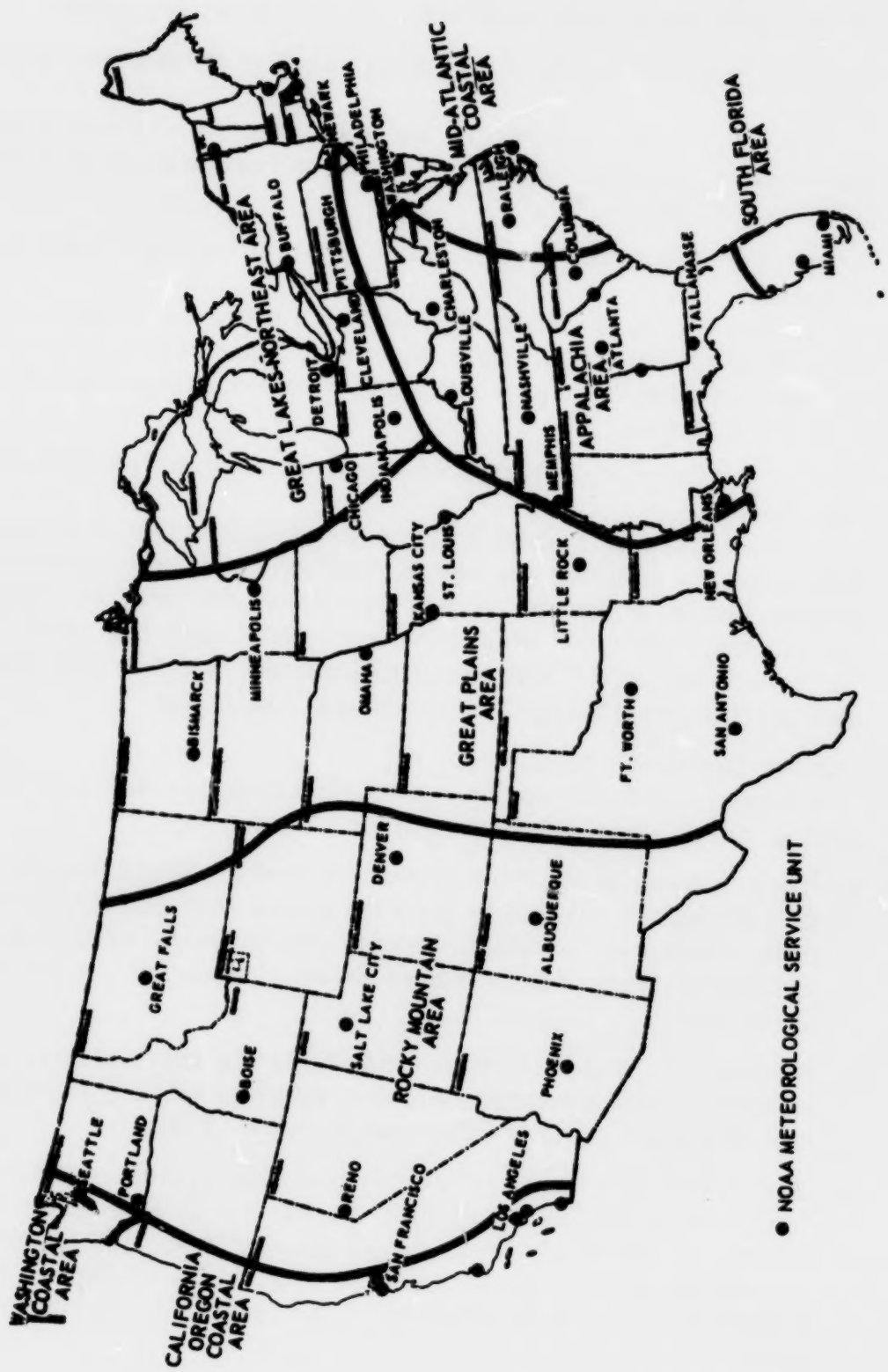

Figure 2-1. Atmospheric areas of the continental United States.

The Appalachian and Rocky Mountain areas are most likely to be dominated by stagnant air masses and light winds. The other areas are usually well ventilated except for local and transitory variations, but the preponderance of sources renders them most subject to episode conditions, especially when local topographical conditions greatly modify the general circulation pattern. Topographic factors that can influence the general pattern include:

1. *Terrain:* Roughness, profile, slope, elevation, valley spacing, and valley width.

   Flat, open terrain is more exposed to broad-scale movement of air than is rough, mountainous terrain, and it is generally less subject to air pollution episodes.

2. *Vegetation:* Dimensional characteristics, physical properties, and distribution.

   Heavily wooded clusters tend to develop a micro-climate under the leafy canopy, marked by light winds and temperature inversion. Pollutants entering this regime may accumulate and persist longer than in nearby open areas.

3. *Hydrology:* Shape, size, distribution, and dynamic properties of nearby water bodies.

   Adjacent land and water surfaces absorb and radiate solar heat differently; the resulting contrast in temperature helps to drive the land-sea breeze during the warmer months of the year. In coastal communities, when the wind systems are weak, pollution tends to "slosh back and forth" with the diurnal reversals of the surface wind, moving off the coast at night and returning inland by day.

4. *Culture:* Degree of urbanization.

   Compared with surrounding countryside, urban areas influence local weather and pollution distributions in the following ways:

   a. *Winds:* Man-made structures reduce the wind speed and channel the flow through streets that lie along the general wind direction. Under some conditions, pollutants become distributed in waffle-shaped patterns following the city plan of streets. Peak concentrations may be lowered.

   b. *Temperature:* Buildings retain incident daytime heat and re-radiate at night to the surrounding air, thus acting to warm it through a layer that is several times higher than the urban skyline.

   c. *Turbulence:* The higher temperature, rougher profile, blocking of wind, and net influx of air into the city act to increase vertical motions of the air above the city. Pollutants that might otherwise accumulate under a nocturnal temperature inversion become distributed through the thicker layer of atmospheric mixing above the city.

   d. *Other Effects:* The above effects, plus the added presence of particulate matter, act to increase cloudiness and precipitation near a

city, particularly downwind from it; precipitation is effective in removing pollutants from the air.

Combinations of topographical factors, coupled with atmospheric processes that vary with season, time of day, and dominating weather-map systems, produce complex local wind patterns. Two patterns associated with terrain configurations are especially important:

1. *Ridges:* Winds tend to follow the orientation of ridges and troughs in "ribbed" or "washboard" terrain. Communities may be receptors for pollution that is channeled over considerable distances along the valleys.
2. *Cup-Shaped Valleys:* An industrial valley that is virtually surrounded by peaks and ridges is particularly prone to hazardous levels of air pollution. During clear, still nights, cold air collects in pools and pockets at the valley bottom and may persist for long periods of time. Daytime heating sets a mountain-valley circulation in motion, but often pollutants are contained within the valley geometry because winds from an overriding weather system fail to penetrate the heavy air below.

2.2.2 Atmospheric Indicators of Episode Development

When the air "feels stale," when persistent layers of smoke and haze lie low over the landscape, and when winds create hardly a stir for several days on end, chances are that the region lies under the dome of a stagnant high-pressure area that covers a major portion of the country. This phenomenon is usually caused by a worldwide slowdown in the normal west-to-east process of the major high- and low-pressure systems. The slowdown may occur several times a year, and situations conducive to high air pollution are not infrequent over the entire United States.

The high pollutant levels that mark the occurrence of air pollution episodes are caused by the accumulation of emissions over urban areas for some time. Day-to-day variations in total emissions do not ordinarily account for the observed rise in ambient concentrations. The principal factor is the meteorological condition. Usually, pollutants are distributed through the atmosphere by the actions of outward-moving winds and upward-moving air currents. From time to time, however, certain features in the atmosphere (inversions) appear to "clamp a lid" over broad areas, limiting vertical transport; slackening winds restrict the horizontal transport of pollutants. When these natural conditions occur in regions with air pollution sources and sensitive receptors and stagnate for an unusually long period of time, episode potential is high.

2.2.2.1 Mixing Height

Of the two atmospheric properties that limit pollutant transport—wind speed and mixing height—the latter is relatively unfamiliar to non-meteorol-

ogists and may need explanation. Physically, mixing height is the vertical extent of turbulent motion within the layer of air next to the ground. The turbulence may be generated by solar heating of the ground, passage of wind across rough surfaces below, or by a combination of both. When the wind is fresh and gusty or when tall cumulus clouds indicate vigorous upward currents from solar heating, the mixing layer is deep and pollutants are well diluted. When the air is still, the ground relatively cold, fog and smoke banks low-lying, and the barometer higher than average, the mixing layer is shallow, and pollutant concentrations could be high. With normal daytime heating, mixing layers that are shallow in the morning deepen considerabley by afternoon. At night, as the ground cools, the mixing height again decreases.

2.2.2.2 Lapse Rate and Stability

A discussion of mixing height requires some explanation of lapse rate and stability. Lapse rate is the rate at which atomospheric temperature is observed to decrease with elevation. It is the vertical temperature profile, which can be measured by balloon-borne radiosonde and other methods. On the average, temperature decreases about 3.5° F with every 1,000 feet of rise, up to the base of the stratosphere some 6 miles high. The decrease is seldom steady, even in the free atmosphere well above the ground. Through some layers, the temperature drop may be faster or slower than through other layers. Sometimes the temperature holds steady through the layer; the layer is then said to be isothermal. Sometimes the temperature rises with ascent; the layer is then said to be an inversion.

If a parcel of air is carried upward by thermal or wind turbulence, it expands and cools at the rate of 5.4° F per 1,000 feet, provided no moisture condenses out. This rate of cooling is called the dry adiabatic lapse rate. Ascending air must be replaced by descending or inflowing air, and a vertical circulation may develop. Descending or subsiding air becomes warmer at the adiabatic rate. Thus, an atmospheric layer characterized by a dry adiabatic lapse rate is or has been a region of significant vertical motion.

In a layer in which the lapse rate exceeds the dry adiabatic (super-adiabatic), vigorous vertical motion can begin "spontaneously." Such a layer is said to be unstable, because the vertical motion is self-perpetuating.

Layers in which the lapse rate is less than the dry adiabatic are said to be stable, because vertical motions are limited. The normal lapse rate of 3.5° F per 1,000 feet describes a stable condition; an isothermal condition is more stable; and an inversion condition in the most stable of all. An inversion layer tends to suppress vertical motion from below. When a mixing layer is shallow, it is often so because a strong inversion caps the surface layers of air.

Figure 2-2 show how an inversion may define the top of a mixing layer. In the morning, the mixing layer hugs the ground at the base of the nocturnal

inversion. As daytime heating erodes the inversion, the mixing layer rises to 1.4 kilometers, about 4,600 feet. Note that the daytime lapse rate is identical to the dry adiabatic lapse rate projected upward from the maximum afternoon temperature at the ground.

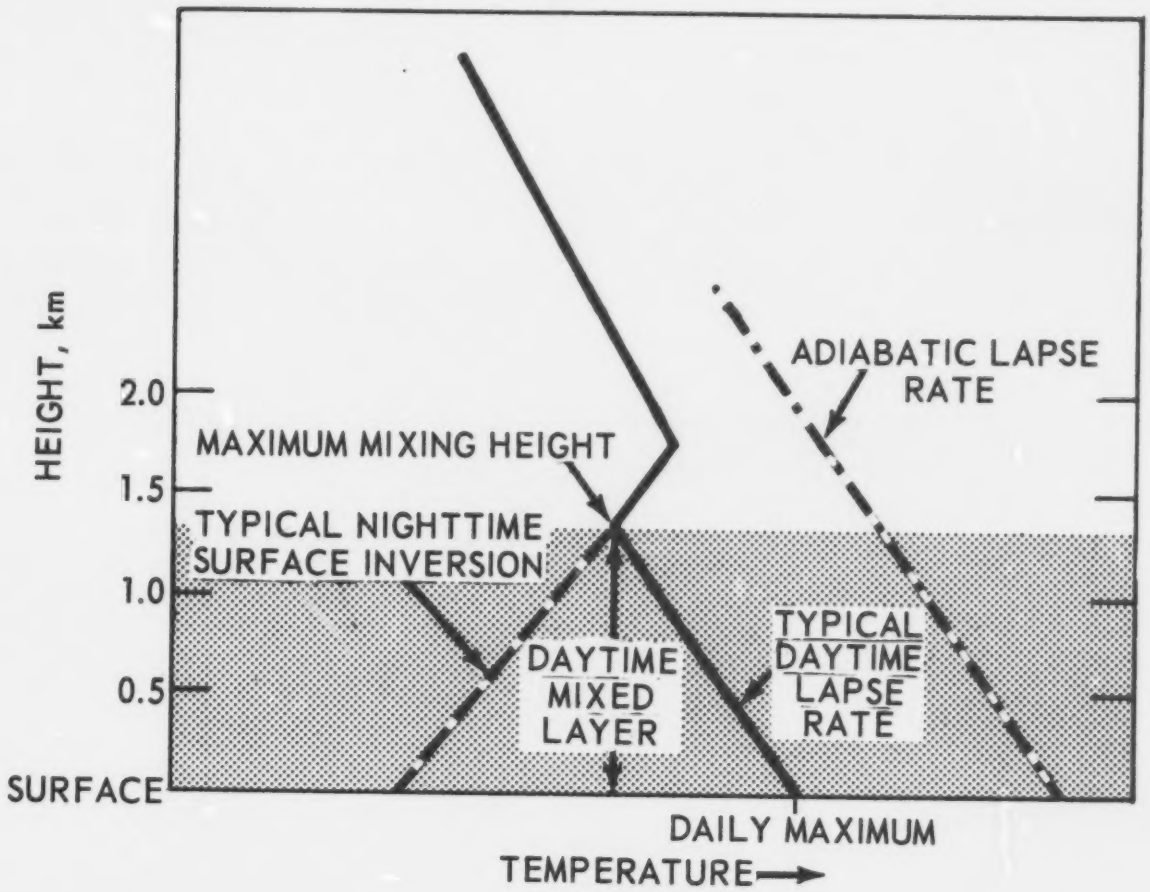

Figure 2-2. Schematic representation of the effect of vertical temperature gradient on atmospheric mixing.

Emissions responsible for episodes are the same as those responsible for "chronic" air pollution. Generally, these emissions are sulfur dioxide, particulates, and oxidants, or combinations of these in different proportions. It is a familiar fact that oxidants are at present the greatest recognized problem in Los Angeles; particulates and sulfur dioxide are serious problems on the East Coast. The need for basing emergency control actions on the local problem is clear. Plans must be flexible because emission characteristics are certain to change with time in kind and quantity due to improved but unequal control of pollutants.

3. EMERGENCY ACTION PLAN

3.1 INTRODUCTION

This section discusses the formulation and operation of a "typical" Emergency Action Plan (EAP). The intent is not to spell out a universal model plan, but to provide a worklist of items that should be considered in designing and implementing a plan. Each area or region contains special conditions and limitations, and each planning item must be considered in the light of local requirements. For those areas that are parts of federally designated Air Quality Control Regions, the State must submit to APCO acceptable Emergency Action Plans as part of the implementation plan for the region.

The necessity for careful and detailed pre-planning cannot be over-emphasized; the time for reaction may be a matter of hours. Planning is necessary to insure that the required equipment, resources, personnel, and procedures are available and the desired communications and control actions are ready to be implemented. An air pollution episode is an unusual event; the emergency actions may be appreciably more drastic than the normal abatement activities undertaken to meet long-term air quality goals.

The major elements of an EAP are shown in Figure 3-1.

In preparing the subsequent material in this section, the following generalizations were made:

1. The existence of an air pollution control authority is essential, that is, the community does have at least one official responsible for air pollution control. The position could be filled by a member of the local health department.
2. The number of significant stationary emission sources is relatively small, approximately five to ten.
3. The community is located in an episode-prone area.
4. The population falls into the 10,000 to 30,000 range and has the municipal services and departments typical of such communities.

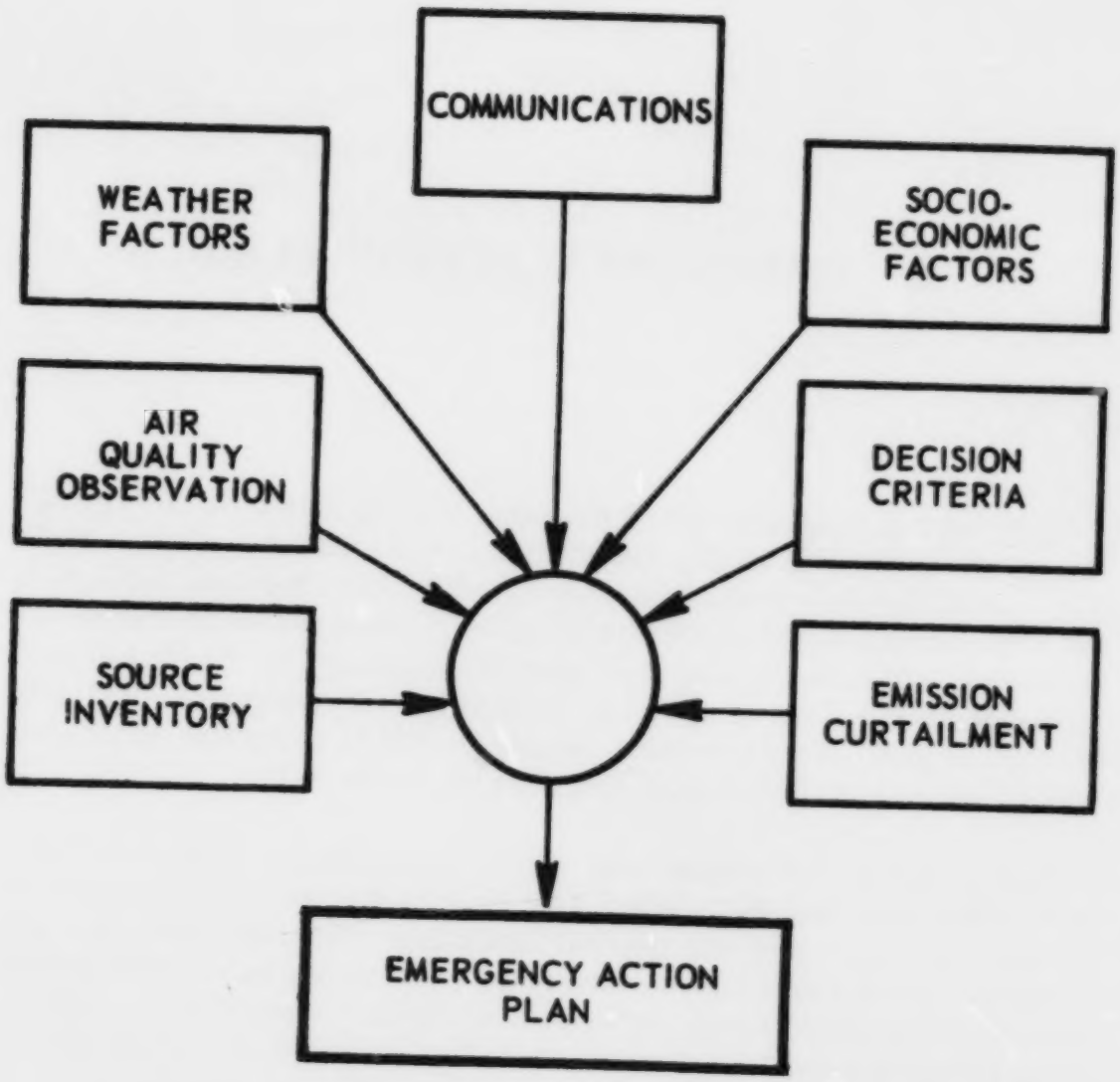

Figure 3-1. Elements of an Emergency Action Plan.

3.2 EMERGENCY ACTION PLAN FORMULATION

There are actually two phases involved in the creation of an EAP. One phase must be formulated for activities within the air pollution control authority itself, while the second relates to the interactions between the authority and others such as governmental agencies, sources of pollution, and news media. The integration of these two elements into a single "master plan" involves the following considerations and activities.

3.2.1 Responsibility and Authority

1. Determine the boundaries of the control area and explore cooperative relations with adjoining areas; decide on interagency strategies in calling alerts; examine special boundary problems.

2. Establish the lines of authority for emergency actions. Local agencies often have authority that has been delegated by the State; but in such cases the final responsibility still lies with the State.
3. Determine whether an advisory emergency committee will be part of the plan; each member should have an alternate.
4. Establish the legal authority to exercise emergency control actions, including civil or criminal law enforcement tools.
5. Obtain the approval of the mayor, appropriate State authority, and APCO (if a federally designated region).

3.2.2 Emergency Action Criteria

1. Assemble the available information on emission sources and air quality to define the local situation.
2. Establish a committee to review and recommend criteria; the committee should include the disciplines of medicine, meteorology, air pollution engineering, government, and law and public safety (police).
3. Review the criteria that have been adopted in other similar areas, if any; prepare arguments for revising them or developing new criteria, considering episode-proneness, local air quality status, and controllable elements.
4. Determine the responsibility and establish procedures for emergency actions.
5. Plan for annual review of criteria, or special review following a major episode.

3.2.3 Background Information

1. Develop emission inventory data, using records of other agencies (Planning, etc.) where possible; develop means for updating periodically.
2. Define the air quality observation program necessary to recognize pre-episode conditions.
3. Define the physical data to be obtained during potential and actual episodes.
4. Establish procedures for reviewing data during potential and actual episodes.

3.2.4 Emergency Source-Curtailment Actions

1. Establish the possible emission-curtailment actions to be taken for:
   a. Power generation.

b. Other industrial sources, by class and size.

c. Commercial sources, by class and size.

d. Incineration and open burning: municipal, commercial, construction, and residential.

2. Establish which actions should be voluntary and which should be mandatory.

3. Define inspection and enforcement procedures, including personnel and equipment requirements.

3.2.5 Communications

1. Establish direct communications with personnel at major emission sources; establish contacts and alternates for each.

2. Determine the information desired by State and Federal authorities and the form in which it is desired.

3. Design the local information system utilizing police, civil defense, public safety, and private communication links; coordinate with each to define their roles. (Police and taxicab radios can serve as emergency communication networks.)

4. Prepare sample news releases; consult with other control agencies experienced in problems of dealing with the public in these matters.

5. Develop recommendations to local medical groups on advising their patients.

3.2.6 Reporting

1. Determine whether legal documentation of data is required; if so, simply the HAPPA bulletin plus local sampling station measurements may suffice.

2. Prepare an outline for a technical summary report; include a record of the times of emission curtailment actions, air quality observations, and observed effects, as well as the climatology of the event.

3.3 EMERGENCY ACTION PLAN IMPLEMENTATION

The EAP provides for the flow of information between different elements and allows for appreciable interaction between the elements. The information flow into the authority includes data on the current status of the atmosphere. Information is also required on both pollutant emissions and the availability of

control actions. The authority interprets the incoming information and, using judgment in conjunction with such tools as atmospheric dispersion estimates, predicts the present and future status of the atmosphere. The prediction is then compared with the air quality criteria established. If the defined levels of pollutant exposure and expected persistence of meteorological conditions are reached, the authority calls an alert.

When an alert has been called, information then flows outward from the authority as planned actions for control of emissions and information dissemination are executed. Typical communications at this point include:

1. Notification to pertinent personnel of requirements for increased air quality observations, meteorological measurements, and inspections.
2. Notification to those people most susceptible to acute health problems.
3. Notification to the public (through news media), interested public officials, and public agencies of the present status.
4. Notification to management of pollutant sources of the requirement to reduce emissions in accordance with the EAP.

As the pollution sources reduce emissions into the atmosphere, the effects are detected by air quality observations; depending on local conditions, pollutant levels either hold, continue to rise, or decrease. If the pollutant levels rise, it may be necessary to take more drastic control actions. Surveillance of air quality and effects continues until the episode terminates. At that point, communications similar to those listed above are utilized to reduce or stop observations, inform all interested public parties, and allow sources to resume normal operating conditions.

The following subsections will discuss those elements both within and outside the authority that must be considered in the implementation of an EAP. Each community will have different requirements, budgets, and legal instruments. It is, therefore, impossible to cover all possibilities, and the reader should relate his circumstances to the discussion with judgment. Familiarity with problems encountered by other similar agencies can be a valuable source of practical information on plan implementation and communication.

3.3.1 Emission Source Inventory

If the impact of emissions from specific sources of pollution is to be estimated, such emissions must be quantified. More importantly, if emissions are to be reduced during episodes, the possible means of curtailment must be identified. It is therefore recommended that the authority obtain as much of the following information, in as much detail as possible, that is available. A questionnaire may be used but, if the number of sources is not too great, visitation and consultation is the method suggested for gathering the following information:

1. General information.

a. Location and property boundaries.

b. Plant capacity, normal and maximum.

c. Fuel usage by shift, month, and season.

d. Fuel type and composition, especially sulfur and ash content.

e. Fuel heating value.

f. Input-material flow rates.

g. Number and frequencies of operating levels if process is continuous.

h. Number and frequencies of "batches" if process is "batch."

i. Source emission height and stack diameter.

j. Emission rate of pollutants per unit of input material.

k. Emission gas flow rates and temperatures, including variation.

l. Individuals (and their telephone numbers) to be contacted on air pollution matters.

m. Type, efficiency, and cost of pollution control equipment.

n. Plans and expansion.

o. Process flow diagrams.

p. Interruptability of batch processes.

2. Dual fuel capability.

   a. Advance notice desired.

   b. Alternate fuel, ash and sulfur content.

   c. Time required to switch fuel.

   d. Seasonal availability of alternate fuel.

   e. Added cost of dual fuel capabilities.

3. Process curtailment capability.

   a. Advance notice required.

   b. Curtailment methods.

   c. Emission rate after curtailment.

   d. Number of employees released on curtailment.

   e. Estimated economic loss per day of curtailment.

In some cases, the source management will not be able to supply pollutant emission rates; if not, rates may be estimated by techniques described in *Compilation of Air Pollutant Emission Factors.*[3] Additional assistance may be obtained from either the appropriate State agency or the Control Agency Development Division, APCO.

3.3.2 Air Quality Observations

3.3.2.1 Pollutant Monitoring

Monitoring of atmospheric pollutants by means of sophisticated continuous equipment is not recommended. Operation of such equipment requires technological skills not usually available within the authority. Furthermore, such units are relatively expensive to install and operate. Some quantification of episode levels should be obtained, however.

For particulate matter, the Spot Tape Sampler may be used. It allows the measurement of spoiling-type particles in the air that generally accumulate during episode conditions. One unit, plus its companion Spot Evaluator, can be purchased for under $1,000. It does not require a highly skilled operator and can be maintained for approximately $200 annually. The Spot Tape Sampler's accuracy and frequency of measurement are sufficient for the purpose of determining episode criteria. Appendix D contains detailed information on this device.

Visual color comparators have been used for short-term measurement of SO_2 and oxidants, including NO_2. The application of such comparators has been restricted to field survey work where electric power and laboratory facilities are limited. The use of visual color techniques for measuring pollutant levels during episode conditions is suggested. Advantages are small initial cost and simplicity of operation. Usually a low-volume air pump (battery operated), suitable for aspirating the air sample through a specific reagent to obtain the desired colored solution, is used. The colored reagent is then matched to a colored glass filter that has the appropriate spectral characteristics of a known concentration of the desired constituent. The major disadvantage of the color comparator is its limited accuracy. Satisfactory agreement (within 20 percent) was obtained between the visual comparator and spectrophotometric methods for SO_2 and NO_2. The oxidant method has been shown to result in values somewhat higher than those obtained with the neutral buffered KI methods. These disadvantages, however, are not a serious obstacle under episode conditions. A sampling train, a comparator, and standard color disks for measuring SO_2, NO_2, and oxidants (with instructions for their use) are commercially available for well under $500.

3.3.2.2 Meteorological Monitoring

For the purpose of episode determination, meteorological monitoring is not recommended for the same reasons advanced for not using sophisticated air quality monitoring. Two courses are open to the local authority to obtain weather information needed to make action decisions.

Arrangements should be made with the Weather Service for the local authority to receive HAPPA bulletins when issued and for consultation with

Weather Service personnel whenever the authority has reason to believe that the locality may be experiencing episode conditions, even though no NOAA advisory has been issued. It is important to note that the NOAA advisories are concerned exclusively with meteorological conditions and not with air quality *per se*. An advisory simply states that atmospheric conditions that are conducive to poor air quality are imminent and are expected to last for a day or more. The burden is then on the authority to determine whether its area of responsibility is indeed affected and, if so, what action should be taken. Appendix C describes the HAPPA Program, and Appendix E shows the Weather Service offices throughout the country.

Meteorological data such as wind speed, wind direction, and mixing depths are also available from the Weather Service. These data should be obtained on an hourly basis during episode periods. If for some reason these data are not available, hourly averages of wind speed and direction may be made by an observer at the local airport.

3.3.2.3 Local Observations

The local authority must also rely heavily upon pertinent information and observations from local sources in order to judge the imminence or severity of an air pollution episode. These data may include:

1. Reports or observations of persistent poor visibility. Hourly visibility measurements should be made and recorded during episode periods. These can be made by observing familiar objects located at known distances from the observer.
2. Reports or observations of malodors. A record of odor location, strength, type, and frequency should be kept. These data can serve as an index to the progression of the episode conditions.
3. Reports from doctors and hospitals on sharp increases in cases involving respiratory and allergic conditions. Daily communications should be established with local medical personnel to obtain data on the occurrence of respiratory ailments during these periods.

3.3.3 Atmospheric Dispersion Estimation

When information relative to the emissions of pollutants from a source, i.e., concentration, height of release, and other physical data (Section 3.3.1), is available in conjunction with data concerning wind speed, direction, atmospheric stability, and mixing height, it is possible for any technically intelligent layman to estimate the dispersion of the pollutants. These estimates can aid in determining the need for a specific source to reduce its emissions in order to avoid an episode. They also allow the authority to predict the relative

accumulation of pollution from specific sources as weather stagnation is forecast to persist.

The reference document for modeling is D. Bruce Turner's *Workbook of Atmospheric Dispersion Estimates,*[4] available on request from APCO's Air Pollution Technical Information Center (APTIC).

The only simplifications recommended beyond those already presented are:

1. Stability: Use D curves for morning conditions, B curves for afternoon.
2. Mixing height: Assume it lies well above the point source plume so that, for downwind concentrations measured over a period of 1 or 2 hours, it is necessary to work only with the Gaussian model.
3. Effective stack height: Add an extra one-third to the known stack height to account for plume rise; or if the average wind is under 4 meters per second, double the stack height.
4. Since wind speed appears in the denominator on the right-hand side of the Gaussian diffusion equation, the expression fails under zero wind conditions. Assume, however, a non-zero wind of 2 meters per second, since wind speed should average out through the mixing layer, and the probability of dead calm through the entire layer is small.

Examples of atmospheric diffusion estimation by means of the described technique are found in Appendix F.

3.3.4 Communications

A potential or actual episode requires rapid control response to changes in meteorological conditions and pollutant levels. This requirement means that the design of a communications plan is one of the most important elements in the implementation of an EAP. A major portion of the communications network is used to transmit status reports and control actions to non-control-agency personnel. Individuals and agencies needing such information include:

1. Public Officials–Mayor, Governor, city council, health commissioner, etc., who may be called upon to participate in a decision-making process.
2. Personnel at Major Emission Sources–Personnel at major emission sources require alert-status reports to effect source control plans designed to reduce emissions. If execution of such plans is mandatory, a formal system may be required for legal notification of the alert status.
3. Public Safety Agencies–The police, fire, civil defense, and public health departments may be assigned definite tasks during an alert and need to

be kept informed on the status of the event. In some locations, existing civil defense, disaster, or emergency networks and procedures may be available for use. The telephone company, though not a public agency, similarly needs to be informed, mainly because of the possibility of overloading facilities.

4. Sensitive Persons—Those people who are most susceptible to acute health problems must be kept advised during an episode. Thus there must be a coordinated effort between the local air pollution officials, public health officials, physicians, hospitals, and the public. It may be ill advised to notify these sensitive people via the public news media as it is important that the physician be able to detect whether a particular patient is reacting physiologically to the pollution levels or psychologically to the episodes. Communicating information through the local health agency or medical society may be more advisable.

5. General Public and News Media—A direct communications link to the major sources of local news media in the area is required. The use of good judgment in dealing with news media is extremely important, and consultation with those experienced in this procedure is highly desirable. An example of a typical episode news release is shown in Figure 3-2.

An office proximate to the local police communications center is recommended for the emergency operations control center. It should be equipped with a minimum of two telephones with separate lines that are at the disposal of the authority during activation of the EAP. Files should be provided for all pre-collected information, necessary workbooks, and references; "desk-top" space for activities such as map-plotting and calculations should be included also.

Staggered schedules for regular communications with observers, emission sources, other public agencies and officials, and the news media must be established in order to prevent "tie-up" of telephone and radio channels of contact.

3.3.5 Socio-Economic Factors

3.3.5.1 Social Considerations

In the broadest sense, social considerations encompass all those factors that relate to human society, the welfare of human beings as members of society, the interaction of the individual and the group, and the cooperative and interdependent relationships of members of the group. This section is restricted to a rather narrow field of human behavior. There are several social factors that the episode planner must prepare for.

1. It must be realized that any action whatsoever that is taken will have a social effect.

NEWS RELEASE - (Date)

_____Agency
Department of Air Pollution Control
(Address)
(City)

FOR IMMEDIATE RELEASE

CONTACT: (Staff Member - Phone No.)

At 12:30 p.m. today (date), the local Weather Service notified the City's Department of Air Pollution Control that weather conditions consisting of a high pressure area and low wind speeds were developing in the metropolitan ___(city)_____ area. These are the same weather conditions that are being formed over the Eastern seaboard from Maine to the Carolinas. These weather conditions are expected to continue until late tomorrow (date) and may result in an increase in the levels of some air pollutants.

"There has been some increase in the levels of sulfur dioxide, but the proportions of other contaminants have not reached a point at which calling of an 'air pollution alert' is necessary or required," stated Mr. _____, (title).

Mr. _____also announced that the Air Pollution Control Department's laboratory had been placed on a 24-hour operational basis. Normally, the staff works a 40-hour week while the instruments measuring air quality record their results continually without attention around the clock. "However", the ___(title)___ said, "in order to be fully cognizant of the problems as they arise, we shall maintain a close watch on the conditions and report to the public if there is need for any specific activity." Mr. _____, air pollution specialist for the ___(city)___ Weather Service, stated that because cool air at the surface was trapped by a lid of warm air aloft, it would remain stagnant over the ___(city)___ area. It is expected that the Department of Air Pollution Control will issue another statement within 24 hours.

Figure 3-2. Sample press release.

2. Generally, these effects will increase with the duration of the episode.
3. Initially, the effects will be in the nature of inconveniences.
4. The effects are primarily those related to restrictions on normal activity and the anxieties associated with a pervasive hazard from which there is no escape.
5. Finally, with some exceptions, these effects disappear at the termination of the episode.

The principal means available to the local authority to minimize these types of social effects is through a program of public education. The episode planner must provide for an effective public information program before, during, and after an episode. The public must be prepared to endure the inconveniences of personal restrictions and to assess calmly the nature of the hazard. Figure 3-3 displays a sample public information approach.

While the public in smaller communities will face only minor inconveniences, such as restriction of backyard refuse burning, certain emotional individuals and some citizens with severe heart or respiratory disease will undoubtedly become alarmed. The local authority must be able to reassure such persons that they will be protected from possible injurious effects by either a reduction of source emissions or a warning to leave the immediate area of high pollution until the episode terminates.

3.3.5.2 Economic Considerations

It is important to appreciate the fact that the benefits of improved air quality are as difficult to assess as are the many costs of air pollution control. As with any health-related control program, the costs involve human factors that are difficult to express as equivalent dollars. For "episode control," the benefits include the avoidance of acute illness and death. The duration of much of the economic impact is a few days; when human lives are involved, the costs involved in control are relatively slight compared to the possible benefits.

During the source inventory, information can be gathered that will assist the authority in evaluating part of the economic impact of emergency action options. It is to industry's advantage to release accurate economic and emission data to help insure that designed actions are realistic and effective. The necessary information may be supplied voluntarily or regulations may be required. The control authority should observe industrial proprietary rights to economic and technical information.

The costs incurred by industry during an episode will be a combination of the fixed or regularly recurring costs associated with being prepared for an episode, and costs approximately proportional to the duration of emergency abatement action during an episode. Both of these classes of costs will vary

WHEN AIR POLLUTION IS HEAVY

Here's what you can do to help yourself and your neighbor

. Use public transportation wherever possible. Use your automobile only if absolutely necessary. If you must drive, try to team up with neighbors or co-workers.

AIR POLLUTION FROM AUTOMOBILES
IS A MAJOR PROBLEM

. Reduce room temperatures to the legal minimum, unless health considerations prevent such action.

AIR POLLUTION FROM HEATING EQUIPMENT
IS A MAJOR PROBLEM

. Stop all outdoor burning.

AIR POLLUTION FROM OPEN OR REFUSE BURNING
IS A MAJOR PROBLEM

. Use as little electricity as possible, either for lighting or appliances.

AIR POLLUTION FROM POWER PLANTS
IS A MAJOR PROBLEM

. Observe the restrictions recommended by your health department or air pollution control agency.

IF YOU SUFFER FROM A RESPIRATORY AILMENT OR HEART CONDITION--

Remain indoors with the windows closed.

Don't smoke. Avoid rooms where others are smoking.

Eliminate unnecessary physical exertion.

Stay under your physician's care.

AIR POLLUTION CONTRIBUTES TO RESPIRATORY DISEASE

Figure 3-3. Flyer published by the National Tuberculosis and Respiratory Disease Association.

widely in magnitude and nature from place to place, among types of industries, and among various plants within each industry. Consequently, data should be collected from each individual plant or plant classification.

3.3.6 Emergency Action Plan Criteria

Following are the suggested EAP criteria that trigger the pre-planned episode emission reduction scheme:

1. Status: *Forecast*–The *Forecast* level indicates that an internal watch will be activated by a Weather Service HAPPA or equivalent report stating that a high air pollution potential will exist for the next 36 hours.

2. Status: *Alert*–The *Alert* level is that concentration of pollutants at which short-term health effects can be expected to occur. An *Alert* will be declared when *any one* of the following levels is reached:

   SO_2–0.3 ppm, 24-hour average
   Particulate–3.0 Coh, 24-hour average
   SO_2 and Particulate combined–Product of 24-hour SO_2 average (ppm) and Coh equal to 0.2
   CO–15 ppm, 8-hour average
   Ox–0.1 ppm, 1-hour average

   and adverse meteorological conditions are expected to continue for 12 or more hours.

3. Status: *Warning*–The *Warning* level indicates that air quality is continuing to deteriorate and that additional abatement actions are necessary. A *Warning* will be declared when *any one* of the following levels is reached:

   SO_2–0.6 ppm, 24-hour average
   Particulate–6.0 Coh, 24-hour average
   Combined SO_2 and Coh–Product of 24-hour SO_2 average (ppm) and Coh equal to 1.0
   CO–30 ppm, 8-hour average
   Ox–0.4 ppm, 1-hour average

   and adverse meteorological conditions are expected to continue for 12 or more hours.

4. Status: *Emergency*–The *Emergency* level is that level at which a substantial endangerment to human health can be expected. These criteria are absolute in the sense that they represent a level of pollution that must not be allowed to occur. An *Emergency* will be declared when it becomes apparent that *any one* of the following levels is imminent:

SO_2 – 1.0 ppm, 24-hour average
Particulate – 10 Coh, 24-hour average
Combined SO_2 and Coh – Product of 24-hour SO_2 average (ppm) and Coh of 2.4
CO – 50 ppm, 8-hour average
75 ppm, 4-hour average
125 ppm, 1-hour average
Ox – 0.4 ppm, 4-hour average
0.6 ppm, 2-hour average
0.7 ppm, 1-hour average

It should be made clear that an Air Pollution Alert, Warning, or Emergency can be declared on the basis of deteriorating air quality alone; a High Air Pollution Potential Advisory need not be in effect. The appropriate episode status should be declared when any monitoring site records ambient air quality below that designated in the criteria. The criteria should be applied to individual monitoring sites and not to area-wide air quality.

The levels used to designate an Air Pollution Emergency are those that pose an imminent and substantial endangerment to public health. Because these levels should not be permitted to occur, an Air Pollution Emergency should be declared when it appears imminent that these levels may be reached.

3.3.7 Emission Curtailment

The reduction of pollutant emissions as a measure to avoid potential episodes requires information not ordinarily available to the local authority. Information pertaining to fuel switching, power interchange, curtailment, and postponement operations can only be obtained through the development of a close and knowledgeable contact with the source management. These data should be obtained as part of the emission inventory. In many instances the switching to a lower-sulfur-content fuel, postponement of refuse combustion, and curtailment of nonessential production operations such as the filling of reservoirs are adequate emission-reduction procedures. Each source management should be required to submit curtailment plans covering the elements as described in the source inventory section, and the operational changes to be made in curtailing emissions.

The public may be requested to help reduce emissions by keeping heating and electrical loads to a minimum. All private incineration and open burning should be curtailed.

The curtailment of major sources can be planned to be implemented on a voluntary basis. The voluntary actions to be taken should be known to the authority, and surveillance should be conducted as though the curtailment were mandatory. Experience to date with voluntary compliance by major

emitters has been excellent, and indicates that pollution control is more easily achieved in the "emergency" case than in the "chronic" case. It is not difficult, however, to obtain legal authority in the form of a court order for curtailment of emissions in an emergency situation. In fact, it is recommended that the legal groundwork be previously laid if a state of extreme noncooperation by personnel at major emission sources is found to exist.

A list of possible actions to be taken to reduce emissions during the two curtailment phases of the EAP are as follows:

1. "Watch" situations:
   a. Delay the start-up of any new industrial process.
   b. Postpone industrial plant start-ups or shutdowns.
   c. Request that all power-generating facilities have available a 5-day supply of low-sulfur fuel (oil or gas) wherever fuel switching is possible.
   d. Request that municipal, home, commercial, and governmental incineration be minimized.
   e. Prohibit all open burning.
2. "Alert" situations:
   a. Prohibit the use of home, municipal, commercial, governmental, and industrial incineration.
   b. Prohibit the use of high-sulfur, high-ash fuels for power generation.
   c. Prohibit the cleaning of storage vessels that contained toxic or odorous compounds.
   d. Request that all industrial sources reduce activities to a minimum, and put into effect all emission curtailment plans.
   e. Request the public to reduce motor vehicle activity, use of electricity, and home heating or air conditioning to a minimum level.

4. SUMMARY

The following items should be considered when formulating a typical EAP. For convenience, they are arranged as an annotated Table of Contents for a typical EAP.

Item	*Remarks*
1. Administration	
1.1 Authorization	Specifies the general functions of the EAP and assigns responsibilities for its operation.
1.2 Purpose	States what the EAP is to accomplish.
1.3 Organization	Defines the relationships within and outside the authority.
1.4 Levels of Activation	As defined in Section 3.3.6.
2. Operations	
2.1 Manning	Specifies the number and skills of personnel involved in the EAP.
2.2 Schedule	Specifies the sequence of EAP operations.
2.3 Duties	Statements of responsibilities.
2.4 Communications	Specifies procedures, schedules, and facilities.
2.5 Data Logging	Instructions for recording of all information.
2.6 Criteria for Activation	As defined in Section 3.3.6.

Item	*Remarks*
2. Operations–Continued	
2.7 Activation Procedures	Specifies the steps required to implement action phases.
2.8 Coordination with Other Agencies	Specifies procedures by which advice and assistance are obtained.
2.9 Means of Emissions Reduction	Specifies control strategies available.
2.10 Decision Criteria	Criteria, designed for the specific community, which trigger voluntary or mandatory controls.
3. Termination of Emergency	
3.1 All-Clear	Criteria for all-clear; specify who must be notified.
3.2 Reverting to Routine	Instructions for terminating operations, releasing personnel, disposition of data, etc.
3.3 After-Action Report	Specifies the format, author, and content of the post-episode report.

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APPENDIX A.

GLOSSARY OF AIR POLLUTION TERMS

1. Acute	Having a sudden onset and a short and relatively severe course.
2. Aerosol	A dispersion of solid or liquid particles of microscopic size in gaseous media. Examples are smoke, fog, and mist.
3. Air Pollution	The presence of unwanted material in the air. The term "unwanted material" refers to material in sufficient amount and under such circumstances as to interfere significantly with comfort, health, or welfare of persons, or with full use and enjoyment of property.
4. Air Pollution Index	One of a number of arbitrarily derived mathematical combinations of air pollutants that gives a single number attempting to describe the amibient air quality.
5. Ambient Air Quality	A physical and chemical measure of the concentration of various chemicals in the outside air. The quality is usually determined over a specific time period (for example, 5 minutes, 1 hour, 1 day).
6. Anticyclone	An area of relatively high atmospheric pressure. In the northern hemisphere, the wind blows spirally outward in a clockwise direction.
7. Atmosphere, The	The whole mass of air, composed largely of oxygen and nitrogen, that surrounds the earth.
8. Atmosphere, An	A specific gaseous mass, occurring either

	naturally or artificially, that can contain any number of constituents and in any proportion.
9. Breathing Zone	That stratum of the atmosphere in which people breathe.
10. Coh	Abbreviation for coefficient of haze, a unit of measurement of visibility interference.
11. Collection Efficiency	The percentage of a specified substance retained by a gas-cleaning or gas-sampling device.
12. Collector	A device for removing and retaining contaminants from air or other gases. Usually this term is applied to cleaning devices in exhaust systems.
13. Combustion	The reaction of carbon-containing substances (or other oxygen-demanding materials) with oxygen, producing a rapid temperature increase in a flame.
14. Density	The mass per unit volume of a substance.
15. Diffusion, Molecular	A process of spontaneous intermixing of different substances, attributable to molecular motion, that tends to produce uniformity of concentration.
16. Dispersion	The most general term for a system consisting of particulate matter suspended in air or other gases.
17. Diurnal	Daily, especially pertaining to actions or events that are completed within 24 hours and that recur every 24 hours.
18. Dust	A term loosely applied to solid particles predominantly larger than colloidal and capable of temporary suspension in air or other gases.
19. Dust Fall	The amount of large particulate matter deposited per month per square mile of land.
20. Dust Loading	An engineering term for "dust concentra-

tion," usually applied to the contents of collection ducts and the emissions from stacks.

21. Droplet — A small liquid particle of such size and density as to fall under still conditions, but which may remain suspended under turbulent conditions.

22. Efficiency — The ratio of attained performance to absolute performance, commonly expressed in percent.

23. Emissions — The total substances discharged into the air from a stack, vent, or other source.

24. Emission Inventory — A list of primary air pollutants emitted into a given community's atmosphere, in amounts (commonly tons) per day, by type of source.

25. Emission Mixture — The total mixture in the atmosphere of emissions from all sources.

26. Environment — The aggregate of all external conditions and influences affecting the life, development, and, ultimately, the survival of an organism.

27. Episode — The occurrence of stagnant air masses during which air pollutants accumulate, so that the population is exposed to an elevated concentration of airborne contaminants.

28. Fly Ash — The finely divided particles of ash entrained in flue gases, arising from the combustion of fuel. The particles of ash may contain incompletely burned fuel.

29. Fog — Visible aerosols in which the dispersed phase is liquid. In meteorology, a visible aggregate of minute water droplets suspended in the air near the earth's surface.

30. Fume — Properly, the solid particles generated by condensation from the gaseous state, generally after volatilization from melted substances and often accompanied by a chemical reaction such as oxidation. Fumes flocculate and sometimes coalesce. Popularly, the term is used in reference to any or all types of contaminants

and, in many laws or regulations, with the added qualifications that the contaminant have some unwanted action.

31. Gas — One of the three states of aggregation of matter, having neither independent shape nor volume, and tending to expand indefinitely.

32. Grab Sample — A sample of an atmosphere obtained in a very short period of time, such that the sampling time is insignificant in comparison with the duration of the operation or the period being studied.

33. Impaction — A forcible contact of particles (often used synonymously with impingement).

34. Impinger — Broadly, a sampling instrument using impingement for the collection of particulate matter.

35. Inversion — A layer of air in which temperature increases with height.

36. Isokinetic — A term describing a condition of sampling, in which the flow of gas into the sampling device, at the opening or face of the inlet, has the same flow rate and direction as the ambient atmosphere being sampled.

37. Mass Concentration — Concentration expressed in terms of substance per unit volume of gas or liquid.

38. Mist — A term loosely applied to dispersions of liquid droplets, the dispersion being of low concentration and the particles of large size. In meteorology, a light dispersion of water droplets of sufficient size to be falling.

39. Month — For reporting analyses of ambient air on a monthly basis, rate results are calculated to a base of 30 days.

40. Odor — That property of a substance that affects the sense of smell.

41. Odor Unit — Unit volume of air at the odor threshold.

42. Odorant — Odorous substance.

43. Opacity Rating	A measurement of the opacity of emissions, defined as the apparent obscuration of an observer's vision to a degree equal to the apparent obscuration of smoke of a given rating on the Ringelmann Chart.
44. Oxidants	A measure of the presence of organic oxidizing chemicals, such as ozone, in the ambient air. An indicator of photochemical smog.
45. Particle	A small discrete mass of solid or liquid matter.
46. Particle Concentrations	Concentration expressed in terms of number of particles per unit volume of air or other gas. Note: In expressing particle concentrations, the method of determining the concentration should be stated.
47. Particle Size	The size of liquid or solid particles expressed as the average or equivalent diameter.
48. Precipitation, Meteorological	The precipitation of water from the atmosphere in the form of hail, mist, rain, sleet, and snow. Deposits of dew, fog, and frost are excluded.
49. Precision	The degree of agreement of reported measurements of the same property. Expressed in terms of dispersion of test results about the mean result, obtained by repetitive testing of a homogenous sample under specified conditions.
50. Pollutant	Any matter that, upon discharge to the ambient air, creates or tends to create a harmful effect upon man, his property, convenience or happiness, or that causes the contamination in ambient air to exceed legally established limits, or that is defined as a pollutant by a regulatory agency.
51. Receptor	Any person or piece of property upon which an air pollutant creates an effect.
52. Ringelmann Chart	Actually a series of charts, numbered from 0 to 5; that simulates various smoke densities by presenting different percentages of black. A Ringelmann No. 1 is equivalent to 20 percent

black; a Ringelmann No. 5, 100 percent. Used for measuring the opacity of smoke arising from stacks and other sources by matching with the actual effluent the various numbers, or densities, indicated by the charts. Ringelmann numbers are sometimes used in setting emission standards.

53. Sampling — A process consisting of the withdrawal or isolation of a fractional part of a whole. In air analysis, the separation of a portion of an ambient atmosphere, with or without simultaneous isolation of selected components.

54. Smog — A combination of "smoke" and "fog." Applied to extensive atmospheric contamination by aerosols arising partly through natural processes and partly from human activities. Often used loosely for any contamination of the air.

55. Smoke — Small gas-borne particles produced by incomplete combustion, consisting predominantly of carbon and other combustible material, and present in sufficient quantity to be detectable in the presence of other solids.

56. Soot — Agglomerations of particles or carbon impregnated with "tar" that are formed in the incomplete combustion of carbonaceous material.

57. Synergism — The cooperative action of separate substances such that the total effect is greater than the sum of the effects of the substances acting independently.

58. Tape Sampler — A device used in the measurement of both gases and fine particulates. It allows air sampling to be done automatically at predetermined times.

59. Thermal Turbulence — Air movement and mixing caused by convection.

60. Topography — The configuration of a surface, including its relief and the position of its natural and man-made features.

61. Vapor	The gaseous phase of matter that normally exists in a liquid or solid state.
62. Volume Concentration	Concentration expressed in terms of gaseous volume of substance per unit volume of air or other gas, usually expressed in percent or parts per million.
63. Week	For reporting analysis of ambient air on a weekly basis, results are calculated to a base of seven consecutive 24-hour days.
64. Year	For reporting analysis of ambient air on a yearly basis, results are calculated to a base of twelve 30-day months.

APPENDIX B.

AIR QUALITY CRITERIA

Table B-1. AIR QUALITY CRITERIA FOR PARTICULATE MATTER[a]

Concentration, $\mu g/m^3$	Measurement methods	Effects	Conditions	Reference
100	Short-term average high-volume sampling	Visibility restriction to < 7.5 miles	Particle sizes in the range of 0.2-1.0μ and R.H. <70%	Charlson et al. Noll et al.
100	High-volume sampling	Damage to materials	Long-term exposure	Larrabee et al. Copson
150-350	Smoke stain calibration or long-term average high-volume sampling	Impairment in lung function or increase in sputum volume of exposed populations	In the presence of 123-300 $\mu g/m^3$ sulfur oxides	Holland et al. Toyama et al. Lunn et al. Fletcher et al.
100-135	Long-term average high-volume sampling	Increased probability of chronic respiratory disease mortality when economic status has been corrected for	Upper temperate latitudes in presence of increased sulfation. Three ranges are given and the concentrations cited are the lower bounds of the two upper ranges	Winkelstein
>130	Long-term average smoke stain calibration	Increased frequency and severity of lower respiratory tract disease in children followed from birth to 15 years	In the presence of concentrations of sulfur oxides above 130 $\mu g/m^3$	Douglas et al.
>300	Smoke stain calibration 24-hr average	Acute worsening of symptoms in bronchitic patients	Upper temperate latitudes in presence of more than 630 $\mu g/m^3$ sulfur oxides	Lawther
800-1000	Smoke stain calibration 24-hr average	Probability of increase in acute illness and death from respiratory and cardiac conditions, especially in persons with chronic cardiopulmonary diseases	In presence of 750-8,000 $\mu g/m^3$ sulfur oxides	Martin et al. Martin Lawther Greenburg et al. Watanabe

[a]The studies referenced here are discussed in National Air Pollution Control Administration Publication No. AP-49, *Air Quality Criteria for Particulate Matter.*

Table B-2. AIR QUALITY CRITERIA FOR SULFUR OXIDES[a]

Effect	SO_2 exposure, ppm	Duration	Comment	Reference
Visibility impairment			Theoretical work is suggestive, but adequate measurements of sulfuric acid and sulfate particles have not been made	
Corrosion	0.03 to 0.12	Annual average	Moist temperate climate with particulate pollution	Upham (1967)
Vegetation damage (alfalfa mostly, but many other species are similarly sensitive)	0.3	8 hr	Laboratory experiment; other environmental factors optimal. Field studies are consistent but dose is difficult to estimate	Thomas (1937) Katz & Mac-Callum (1952)
Odor threshold	0.47 ppm. 50% of subjects detect	<1 hr	May be higher for many persons or when other methods are used	Manufacturing Chem. Assn. (1968)
Respiratory symptoms	0.2	Daily average	Community exposure exceeding 0.2 ppm more than 3% of the time	Bell (1962)
Respiratory symptoms	>0.05	Long-term average	With particulates >100 $\mu g/m^3$	Holland-Stone (1965), Deane-Goldsmith-Tuma (1965)
Respiratory symptoms	0.2	Daily average	With particulates	McCarroll (1966)
Respiratory symptoms	0.9	Hourly average	With particulates	Cassell (1965)
Respiratory symptoms, plus impairment of lung function in children	>0.05	Monthly average	With particulates	Toyama (1964)

[a]The studies referenced here are discussed in National Air Pollution Control Administration Publication No. AP-50, *Air Quality Criteria for Sulfur Oxides.*

Table B-3. AIR QUALITY CRITERIA FOR CARBON MONOXIDE[a]

Concentration and method	Duration of averaging	Effect	Comments	Reference
More than 10-12 ppm NDIR	4-5 hr	Increased COHb 0.5-2%.	Traffic police in Paris and Detroit and students in Los Angeles. May be overwhelmed by smoking exposure.	Chovin et al. Clayton et al.
About 10 ppm NDIR	24 hr	Possibly increased risk of auto accidents	Epidemiological association. Smoking or alcohol use might contribute or the association might be spurious. Being studied in Los Angeles 1963-1968.	Chovin et al. Clayton et al.
More than 8 ppm NDIR	Weekly average	Possibly increased case fatality rate in hospitalized myocardial infarction patients	Higher case fatality in L.A. area with higher pollution during the quartile of weeks with highest CO levels. 1958 data need to be confirmed with later data. Other factors may be involved.	Cohen et al.
Mean of 50 ppm MSA Colorimetric	8 hr	Increased hematocrit. COHb mean of 3.8% in smokers and 3.4% in nonsmokers	All occupational exposure data do not show an effect on hematocrit.	Hofreuter
30 ppm NDIR	8-12 hr	Equilibrium value of 5% COHb reached	Experimental exposure of nonsmokers.	Smith State of California, Department of Public Health
50 ppm NDI	90 min	Threshold for the impairment in time discrimination. Unpublished data show this effect with substantially shorter exposures	COHb levels not available, but expected values about 2%. Certain psychomotor test results were impaired at 2% COHb.	Beard et al. Schulte
100-300 ml Injection of pure gas into airstream	10-15 min	Impairment of visual function detectable at 4-5% COHb	Data given for very small number of subjects.	Halperin et al.

[a]The studies referenced here are discussed in National Air Pollution Control Administration Publication No. AP-62, *Air Quality Criteria for Carbon Monoxide.*

Table B-4. AIR QUALITY CRITERIA FOR OZONE BASED ON HEALTH EFFECTS[a]

Effect	Exposure, ppm	Duration	Comment	Reference
Odor detection	0.02	5 min	Odor detected in 9/10 subjects within 5 min	Henschler et al.
Respiratory irritation (nose and throat), chest constriction	0.3	Continuous during working hours (8 hr)	Occupational exposure of welders (other pollutants probably also present).	Kleinfeld et al.
Changes in pulmonary functions: Diminished $FEV_{1.0}$ after 8 weeks	0.5	3 hr/day 6 days/week for 12 weeks	Experimental exposure. Change returns to normal 6 weeks after exposure. No changes observed at 0.2 ppm.	Bennett
Small decrements in VC, FRC, and DL_{CO} in, respectively, 3, 2, and 1 out of 7 subjects	0.2-0.3	Continuous during working hours	Occupational exposure. All 7 subjects smoked. Normal values for VC, FRC, and DL_{CO} based on predicted value.	Young et al.
Impaired diffusion capacity (DL_{CO})	0.6-0.8	2 hr	Experimental exposure of 11 subjects	Young et al.
Increased airway resistance	0.1-1.0	1 hr	Increase in 1/4 at 0.1 ppm and 4/4 at 1.0 ppm.	Goldsmith et al.
Reduced VC, severe cough, inability to concentrate	2.0	2 hr	High temperatures. One subject.	Griswold et al.
Acute pulmonary edema	9.0	Unknown	Refers to peak concentration of occupational exposure. Most of exposure was to lower level.	Kleinfeld et al.

[a]The studies referenced here are discussed in National Air Pollution Control Administration Publication No. AP-63, *Air Quality Criteria for Photochemical Oxidants.*

Table B-5. AIR QUALITY CRITERIA FOR OXIDANTS BASED ON HEALTH EFFECTS[a]

Effects	Exposure, ppm	Duration	Comment	Reference
Eye irritation	0.1	5 min	Result of panel response.	Renzetti and Gobran
Impairment of pulmonary function (airway resistance)	Regression about 0.1	1 week in room containing ambient air	Subjects were smokers and nonsmokers. Most subjects had emphysema.	Remmers and Balchum
Aggravation of respiratory disease: asthma	0.13[b]	Continuous	Patients exposed to ambient air. Value refers to oxidant level at which number of attacks increased.	Schoettlin and Landau
Impaired performance of student athletes	Regression about 0.1	1 hr +	Exposure for 1 hour immediately prior to race.	Wayne et al.

[a]The studies referenced here are discussed in National Air Pollution Control Administration Publication No. AP-63, *Air Quality Criteria for Photochemical Oxidants.*

[b]Calculated from a measured value of 0.25 ppm (phenolphthalein method), which is equivalent to 0.13 (KI).

APPENDIX C.

HIGH AIR POLLUTION POTENTIAL ADVISORY PROGRAM

An air pollution potential message is issued every day at 12:20 p.m., EST, by the Weather Service National Meteorological Center (NMC) located at Suitland, Maryland. The message is disseminated over the Service C Network. It has two parts: a plain-language narrative and a coded message. The narrative identifies areas for which an air pollution potential condition is forecast. If no air pollution potential areas are likely, the statement is "None Today." The narrative may include information added at the forecaster's discretion, such as a developing situation that does not yet meet the rigid criteria for issuance of an advisory.

The coded message provides information on current and predicted mixing heights and average wind speed in the mixing layer for all reporting Weather Service radiosonde stations in the United States. Computations are based upon data for 7:00 a.m., EST, which is the time of synoptic upper air soundings everywhere in the world. Since a vast quantity and variety of data must be processed to produce the coded message, the entire procedure is computerized, including the punched paper tape for disseminating the message on teletype circuits.

The NMC forecaster uses the machine-calculated data as a guide in determining whether an air pollution potential advisory is warranted. His decision depends largely upon whether all of the following criteria are met:

1. The affected area must be no smaller than an area approximately equivalent to a 4-degree latitude-longitude square (about the size of Oklahoma).
2. No significant precipitation or frontal passages must be observed or expected for the next 36 hours or so.
3. The surface winds at stations in the area must not average more than 5 knots and/or no more than three individual hourly wind speeds are to exceed 8 knots during a 24-hour period.

4. The morning urban mixing height must be < 500 meters (about 1,600 ft), and the observed average wind speed through this layer must be < 4 meters/sec (about 9 mph).

5. The numerical product of the afternoon mixing height and the forecast average wind speed through this layer must be < 6,000 m^2/sec, *and* the forecast average wind itself must not exceed 4 m/sec.

6. The 30-hour forecast of the following afternoon's mixing height and average wind speed must meet the same criteria as in 2. above.

These criteria may appear to be overly stringent. Situations in which all criteria are satisfied should occur infrequently, and many local air pollution events would not be covered by HAPPA advisories. This is not unplanned.

"This conservatism on the part of the APP forecaster is by design. In simple terms, he does not wish to be accused of crying Wolf! The social and economic consequences of a substantial air pollution episode are sufficiently great such that the APP forecaster would rather miss a few marginal cases than attempt to forecast all possibilities and cry APP when none came to pass. He would soon be ignored to the eventual detriment of the ignorers. Rather he would prefer that his forecasts came to be trusted so that preventative measures, reducing smoke production, changing fuel types, and generally restricting pollutant production, could be undertaken to avoid the possible disastrous consequences of a failure to act.

At present, nothing seemingly can be done about changing the potential; however, adequate warning coupled with firm measures can go a long way toward eliminating the Air Pollution in an air pollution potential episode."[1]

REFERENCE FOR APPENDIX C

1. Stackpole, J. D. The Air Pollution Potential Forecast Program. Weather Bureau Technical Memorandum NMC-43. Suitland, Md. November 1967.

APPENDIX D.

TAPE SAMPLER

D.1 PRINCIPLE AND APPLICABILITY

D.1.1 Ambient air is drawn through a circular portion of a continuous strip of filter paper tape 2 inches wide. Particulate matter impinges on the filter tape in a spot 1 inch in diameter. The sampling spot is automatically advanced every 2 hours on even-hour increments by a timer and take-up reel mechanism. In the National Air Surveillance Network, the samplers are operated continuously, and the tapes are cut weekly, usually after the 8:00 to 10:00 a.m. spot on Monday.

D.1.2 The spot on the tape is measured in Coh's (from "coefficient of haze") per 1,000 linear feet of sampled air. Mesaurement is based on light transmission through the spot sample; clean areas in front of each spot are used as a reference. Such measurement describes the quantity of particulate matter in the air in terms of soiling properties.

D.2 RANGE AND SENSITIVITY

D.2.1 In relatively clean atmospheres, the amount of particulate collected may be insufficient to cause any measurable difference between the reference blank and the spot. In some cases, the spot may give a negative reading. Such data are not tabulated. A sampling rate of 15 standard cubic feet per hour and a sampling time of 2 hours per spot produce the greatest amount of translatable data.

D.3 INTERFERENCES

D.3.1 Rain and condensation tend to stain the paper filter tape; the resulting darkened area bears no relation to soiling characteristics of the atmosphere, because the moisture apparently washes out the sampling tube.

Care therefore must be taken to keep the inlet funnel upside down and the sampling tube as short as possible.

D.4 PRECISION, ACCURACY, AND STABILITY

D.4.1 Accuracy of airflow measurement is important. Flow through the filter tape should be set at 15 standard cubic feet per hour. The flow must then be maintained at 15 and should be checked twice daily. Each instrument must be individually calibrated on site with an accurate wet-test meter. Thickness and optical density of the paper tape should be uniform.

D.5 APPARATUS

D.5.1 Sampling

D.5.1.1 Tape Sampler–The instrument consists of a rotary vane vacuum pump, whose flow is measured by a push-to-test flowmeter (range 0 to 30) and is adjusted by a needle valve; an automatic timer set for 2-hour intervals; and an electric take-up motor with necessary electromechanics to change sampling spots automatically.

D.5.1.2 Filter Paper Roll–Whatman No. 4 filter paper or equivalent, 2 inches wide, indexed with 1/8-inch holes every 2 inches.

D.5.2 Analysis

D.5.2.1 Optical Density Measuring Instrument–Capable of measuring the optical density of light transmitted through the tape.

D.5.2.2 Automatic Spot Evaluator (optional)–This instrument is convenient when large amounts of data are collected. It automatically advances the tape to each spot, measures light transmission through the spot and reference area, digitizes the reading, and makes it available for automatic data processing equipment.

D.6 REAGENTS–None required for sampling or analysis.

D.7 PROCEDURE

D.7.1 Sampling

D.7.1.1 Thread a new roll of spot tape in the supply reel through the sampling block and attach to the tape take-up reel core. Turn on the sampler, and set the timer at zero. Next, set the flowmeter to correspond with a calibration curve previously obtained to give 15. Turn off the sampler and wait until an even hour (e.g., 8:00, 10:00, 12:00), then turn on the sampler. The tape will automatically advance to a clean spot.

D.7.1.2 Check the flowmeter at least twice daily and adjust, if necessary, to obtain a true flow of 15.

D.7.1.3 Cut the tape weekly for optical density measurement. Leave about a foot of blank tape on each end for ease of processing and protection. When removing the tape, mark a beginning and ending date and the time on the appropriate ends. Mark the date and time on the edge of the tape each day, usually when the airflow is checked. Do not mark in areas that pass through the translator light beam and optical cell area; use only the lower 1/4 inch for marking purposes. Handle the tape by the edges, and do not allow it to pick up dirt, grease, or moisture.

D.7.2 Analysis

D.7.2.1 Install the exposed tape in the optical-density measuring instrument and read as directed by instrument instructions.

D.8 CALIBRATION

D.8.1 Airflow through the clean filter paper must be maintained at 15. A wet-test meter may be used if other conditions are standardized. A calibration curve must be drawn to relate true flow and flowmeter readings in the range of 10 to 20. Flow rate can vary with differences in filter thickness and particulate loading.

D.8.2 The optical density measuring instrument must also be calibrated with standard optical densities.

D.9 CALCULATIONS

D.9.1 The Coh is defined as "the quantity of light-scattering solids deposited on the standard filter tape that produces an optical density of 0.01 when measured by white-light transmittance (where the blank filter is 0 optical density).

$$\text{Coh's} = \frac{\text{measured optical density}}{\text{optical density per Coh}}$$

$$\text{Coh's} = \frac{\text{measured optical density}}{0.01}$$

D.9.2 Optical density (OD) is defined as the logarithm to the base 10 of the reciprocal of the transmittance.

$$OD = \log_{10} \frac{I}{T} = \log_{10} \frac{100}{\%\ \text{transmittance}} = \log_{10} \frac{I_o}{I}$$

where:

T = transmittance

I_o = intensity of light transmitted through the clean area adjacent to the spot

I = intensity of light transmitted through the spot.

D.9.3 Data are reported in Coh's per 1,000 linear feet of an air column of cross-sectional area equal to that of the spot.

$$\text{Lineal feet} = \frac{\text{sampled volume}}{\text{area of sample spot}} = \frac{ft}{A_{spot}}$$

where: F = sample flow rate, ft^3/min

t = sample time, min

A_{spot} = area of the spot, ft^2

Therefore:

$$\text{Coh's per 1,000 lineal ft} = \frac{100\ (\text{measured OD of spot} - \text{measured OD of blank})}{\frac{ft}{1{,}000\ A_{spot}}}$$

$$\text{or} \quad \frac{\text{Coh's}}{\text{1,000 lineal ft}} = \frac{10^5\ A_{spot}\ (\text{OD of spot} - \text{OD of blank})}{ft}$$

D.10 BIBLIOGRAPHY

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APPENDIX E.

NATIONAL WEATHER SERVICE STATIONS

IN UNITED STATES

ALABAMA
1. MOBILE
2. HUNTSVILLE
3. BIRMINGHAM
4. MONTGOMERY

ARIZONA
1. YUMA
2. PHOENIX
3. FLAGSTAFF
4. WINSLOW
5. TUCSON

ARKANSAS
1. FORT SMITH
2. LITTLE ROCK
3. TEXARKANA

CALIFORNIA
1. EUREKA
2. OAKLAND
3. SAN FRANCISCO
4. SANTA MARIA
5. BURBANK
6. LOS ANGELES
7. LONG BEACH
8. SAN DIEGO
9. MOUNT SHASTA
10. RED BLUFF
11. SACRAMENTO
12. STOCKTON
13. FRESNO
14. BAKERSFIELD
15. POMONA

COLORADO
1. GRAND JUNCTION
2. ALAMOSA
3. DENVER
4. COLORADO SPRINGS
5. PUEBLO

CONNECTICUT
1. BRIDGEPORT
2. NEW HAVEN
3. HARTFORD

DELAWARE
1. WILMINGTON

DISTRICT OF COLUMBIA

FLORIDA
1. PENSACOLA
2. APALACHICOLA
3. TALLAHASSEE
4. JACKSONVILLE
5. ORLANDO
6. DAYTONA BEACH
7. TAMPA
8. LAKELAND
9. FORT MYERS
10. PALM BEACH
11. MIAMI
12. KEY WEST

GEORGIA
1. COLUMBUS
2. ATLANTA
3. MACON
4. ATHENS
5. AUGUSTA
6. SAVANNAH

IDAHO
1. LEWISTON
2. BOISE
3. POCATELLO

ILLINOIS
1. MOLINE
2. ROCKFORD
3. CHICAGO
4. PEORIA
5. SPRINGFIELD
6. CAIRO

INDIANA
1. EVANSVILLE
2. SOUTH BEND
3. INDIANAPOLIS
4. FORT WAYNE

IOWA
1. SIOUX CITY
2. DES MOINES
3. WATERLOO
4. DUBUQUE

KANSAS
1. GOODLAND
2. DODGE CITY
3. CONCORDIA
4. WICHITA
5. TOPEKA

KENTUCKY
1. LOUISVILLE
2. LEXINGTON

LOUISIANA
1. SHREVEPORT
2. ALEXANDRIA
3. LAKE CHARLES
4. BATON ROUGE
5. NEW ORLEANS

MAINE
1. CARIBOU
2. PORTLAND

MASSACHUSETTS
1. WORCESTER
2. BOSTON
3. NANTUCKET

MARYLAND
1. FREDERICK
2. BALTIMORE

MICHIGAN
1. MARQUETTE
2. ESCANABA
3. SAULT STE. MARIE
4. ALPENA
5. HOUGHTON LAKE
6. MUSKEGON
7. GRAND RAPIDS
8. LANSING
9. FLINT
10. DETROIT

MINNESOTA
1. INTERNATIONAL FALLS
2. DULUTH
3. ST. CLOUD
4. MINNEAPOLIS
5. ROCHESTER

MISSISSIPPI
1. VICKSBURG
2. JACKSON
3. MERIDIAN

MISSOURI
1. KANSAS CITY
2. SPRINGFIELD
3. COLUMBIA
4. ST. LOUIS

MONTANA
1. KALISPELL
2. MISSOULA
3. HELENA
4. GREAT FALLS
5. HAVRE
6. BILLINGS
7. GLASGOW

NEBRASKA
1. SCOTTS BLUFF
2. VALENTINE
3. NORTH PLATTE
4. GRAND ISLAND
5. NORFOLK
6. LINCOLN
7. OMAHA

NEVADA
1. RENO
2. WINNEMUCCA
3. ELKO
4. ELY
5. LAS VEGAS

NEW HAMPSHIRE
1. CONCORD

NEW JERSEY
1. TRENTON
2. NEWARK
3. ATLANTIC CITY

NEW MEXICO
1. SILVER CITY
2. ALBUQUERQUE
3. ROSWELL

NEW YORK
1. BUFFALO
2. ROCHESTER
3. SYRACUSE
4. ALBANY
5. BINGHAMTON
6. NEW YORK CITY

NORTH CAROLINA
1. ASHEVILLE
2. CHARLOTTE
3. WINSTON-SALEM
4. GREENSBORO
5. RALEIGH
6. WILMINGTON
7. CAPE HATTERAS

NORTH DAKOTA
1. WILLISTON
2. BISMARCK
3. FARGO

OHIO
1. CINCINNATI
2. DAYTON
3. TOLEDO
4. COLUMBUS
5. MANSFIELD
6. CLEVELAND
7. AKRON-CANTON
8. YOUNGSTOWN

OKLAHOMA
1. OKLAHOMA CITY
2. TULSA

OREGON
1. ASTORIA
2. SALEM
3. EUGENE
4. MEDFORD
5. PORTLAND
6. PENDLETON

PENNSYLVANIA
1. ERIE
2. PITTSBURGH
3. WILLIAMSPORT
4. READING
5. HARRISBURG
6. SCRANTON
7. ALLENTOWN
8. PHILADELPHIA

RHODE ISLAND
1. PROVIDENCE

SOUTH CAROLINA
1. GREENVILLE-SPARTANBURG
2. COLUMBIA
3. CHARLESTON

SOUTH DAKOTA
1. RAPID CITY
2. ABERDEEN
3. HURON
4. SIOUX FALLS

TENNESSEE
1. MEMPHIS
2. NASHVILLE
3. CHATTANOOGA
4. KNOXVILLE
5. BRISTOL

TEXAS
1. EL PASO
2. AMARILLO
3. LUBBOCK
4. MIDLAND
5. DEL RIO
6. LAREDO
7. ABILENE
8. SAN ANGELO
9. WICHITA FALLS
10. FT. WORTH
11. DALLAS
12. WACO
13. SAN ANTONIO
14. AUSTIN
15. VICTORIA
16. CORPUS CHRISTI
17. BROWNSVILLE
18. HOUSTON
19. PORT ARTHUR
20. GALVESTON

UTAH
1. WENDOVER
2. SALT LAKE CITY

VERMONT
1. BURLINGTON

VIRGINIA
1. ROANOKE
2. LYNCHBURG
3. RICHMOND
4. NORFOLK

WASHINGTON
1. SEATTLE
2. OLYMPIA
3. WENATCHEE
4. YAKIMA
5. SPOKANE
6. WALLA WALLA

WEST VIRGINIA
1. HUNTINGTON
2. PARKERSBURG
3. CHARLESTON
4. BECKLEY
5. ELKINS

WISCONSIN
1. LA CROSSE
2. MADISON
3. GREEN BAY
4. MILWAUKEE

WYOMING
1. LANDER
2. SHERIDAN
3. CASPER
4. CHEYENNE

Figure E-1. National Weather Service Stations in United States.

APPENDIX F.

EXAMPLE PROBLEMS IN DIFFUSION ESTIMATION

The solutions to the problems listed below refer to tables and figures found in Bruce Turner's *Workbook of Atmospheric Dispersion Estimates,* available from the Environmental Protection Agency's Air Pollution Control Office as PHS Publication No. 999-AP-26 (revised 1969).

PROBLEM 1. A power plant burns 10 tons per hour of coal containing 3% sulfur; the effluent is released from a single stack with effective height of emission of 150 meters. On a sunny afternoon, with the wind at 4 m/sec, what is the distance to the maximum ground-level concentration, and what is the concentration at that point?

SOLUTION: To determine the source strength, the amount of sulfur burned is: 10 tons/hr x 2,000 lb/ton x 0.03 sulfur = 600 lb sulfur/hr. Sulfur has a molecular weight of 32 and combines with 0_2 with a molecular weight of 32; therefore, for every mass unit of sulfur burned, there result two mass units of SO_2.

$$Q = \frac{2 \times (600 \text{ lb/hr} \times 453.6 \text{ g/lb})}{3600 \text{ sec/hr}} = 151 \text{ g/sec } SO_2$$

Turn to Figure 3-9 on p. 29 of the Workbook, For a sunny afternoon, consider stability to be in Class B. Using the curve marked B, at effective height of 150 meters, read the Y-coordinate as 1 km for the downwind distance to the point of maximum concentration. Read the X-coordinate as 7.5×10^{-6} for maximum $\chi u/Q$, which is the "normalized" concentration. Multiply the last figure by Q/u to get χ_{max}:

$$\chi_{max} = \frac{\chi u \ Q}{Q_{max} \ u} = \frac{7.5 \times 10^{-6} \times 151}{4} = 2.8 \times 10^{-4} \text{ g/m}^3 \ SO_2$$

$$= 2800 \ \mu\text{g/m}^3 = 0.098 \text{ ppm NPT}$$

PROBLEM 2: For the power plant in Problem 1, at what distance does the maximum ground-level concentration occur, and what is this concentration under nighttime or heavy overcast conditions?

SOLUTION: Use D stability curve. From Figure 3-9, D stability, at H of 150 m, distance to the point of maximum ground level concentration is 5.6 km, and the maximum normalized concentration is 3.0×10^{-6}.

$$\chi_{max} = \frac{3.0 \times 10^{-6} \times 151}{4} = 1.1 \times 10^{-4} \text{ g/m}^3 = 110 \,\mu\text{g/m}^3 = 0.0375 \text{ ppm NPT}$$

PROBLEM 3. Under conditions of Problem 1, what concentration would be measured at a point 1.5 km downwind, and 200 m off to the side of the plume direction?

SOLUTION: Turn to Figure 3-5B. Refer to 1.5 km along the abscissa, follow the line up the chart to where it intersects the curve for H = 150, then read across to the left, 6.0×10^{-6} for normalized concentration. However, this applies to the center line of the plume.

Now turn to Figure 3-2. At downwind distance of 1.5 km, follow the line up the chart to where it intersects the curve for B, and read to the left a value for σ_y of 225 m. This is the standard deviation of the lateral spread of the plume concentration. Our point of interest is 200/225 of the distance of the standard deviation, or 0.889. Turn to Table A-1, on page 66, and read for 0.889 a value of 6.73×10^{-1}. This is the factor to be applied to the centerline concentration. Hence,

$$(\chi u/Q)_{x,y} = 6.0 \times 10^{-6} \times 0.673 = 4.038 \times 10^{-6}$$

$$\chi_{x,y} = \frac{4.038 \times 10^{-6} \times 151}{4} = 152.5 \times 10^{-6} \text{ g/m}^3$$

$$= 152.5 \,\mu\text{g/m}^3 = 0.053 \text{ ppm NPT}$$